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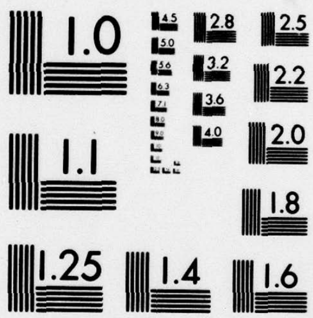

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Technical Report
MII Project M-227
March 1978

DEVELOPMENT OF A MARINE HISTORY OF ANALYZED SEA-LEVEL PRESSURE FIELDS AND DIAGNOSED WIND FIELDS

by

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Climatology	Fields by Information Blending

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Using a highly-developed and flexible objective analysis technique, over 16.5 million synoptic observations made by ships at sea were blended with archived meteorological fields to produce re-analyzed sea-level pressure fields for the Northern Hemisphere on a 63x63 grid (polar stereographic projection). These sea-level pressure fields, covering a period of 30 years (1946-1975) in 6-hourly increments, were used to diagnose sea-level wind fields for the same times. There are many potential uses for these high-quality fields of sea-level → cont

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pressure and wind, the first application being to use the wind fields to drive the FNWC Spectral Wave Model--thus producing a 30-year 6-hourly set of wave fields. Other potential uses of the data bases established by the project are suggested in the Report.

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1. INTRODUCTION

By the mid-1960's, the records of the millions of meteorological observations that had been made by ships over the preceding century or so, lay in a large number of national repositories; no attempt had been made to collect and assemble all these observations into a comprehensive data base. Although the potential value of such a data base was recognized, it was not until modern computer-based techniques for handling large quantities of data had been evolved that the task became feasible. The enormous task of collecting and assembling the back-log of marine observations into a common data base was begun in 1966 and continued until 1972, with funding being provided jointly by the Naval Weather Service Command, the Environmental Science Services Administration, and the Department of Defense. This unique and invaluable data base, containing reports dating as far back as 1854, represents a monumental effort not only in the taking of the observations but also in the collecting, digitizing and organizing of the data on magnetic tape.

There are many potential uses for this data base, some of which are detailed in Section 7. In 1975 it was decided that a major fulfillment of the effort and expense involved in establishing the data base would be to undertake the project of producing a Marine History, consisting of a re-analysis of Northern Hemisphere sea-level pressure on a 63x63 grid (polar stereographic projection) at 00Z, 06Z, 12Z and 18Z for a period of 20 years (1956-1975). These analyses were to be used to diagnose wind fields which, in turn, were to be used to drive the FNWC Spectral Wave Model--thus producing the objective of a 20-year 6-hourly set of wave fields.

The original data base had been organized into a format unsuitable for the production of synoptic analyses (see Section 3.1) and, consequently, the first task was to extract the relevant data from the main data base and

carry out the necessary organization. This work was carried out by Meteorology International Incorporated on behalf of FNWC.

The next task, the production of the planned 20-year history of sea-level pressure, was addressed by Contract No. N00228-76-C-3273 which was awarded to MII. The intention at the time the contract was first placed was to produce 6-hourly sea-level pressure fields for a period of 20 years, i.e., from 1956-1975, but data limitations restricted realistic production to the period 1956-1972. However, from 1971 onwards, high-quality sea-level pressure analyses (4 per day) were produced by FNWC using an earlier version of the analysis methodology outlined in Section 4.1. The first 20-year installment of the Marine History was produced, therefore, by carrying out a re-analysis for the period 1956 to 1971, then adding on the later high-quality analyses--thus covering a total period of 20 years (1956-1975).

Production of the planned 20-year re-analysis of Marine History, together with the production of the associated diagnosed wind fields, was completed in mid-1977.

It was then decided to extend the period of re-analysis by ten years to cover the total period 1946-1975. This work--including the necessary augmentation of the synoptic data base of marine observations and the production of the diagnosed wind fields--has been carried out by MII under an amendment to the contract.

The principal subject of this report is the utilization of the data base of marine observations, as well as other data, to develop the Marine History of analyzed sea-level pressure fields and diagnosed wind fields. (Note that the derivation of the spectral wave fields from the diagnosed wind fields did not form part of Contract No. N00228-76-C-3273; this derivation is being carried out in-house by FNWC). As will be appreciated, the description of the production of the total 30-year period of the Marine History--both

sea-level pressure fields and the associated diagnosed wind fields--would be unnecessarily complicated by following the actual sequence of events. Therefore, to simplify the account, this Technical Report is written from the viewpoint that the project was performed as a coherent whole.

2. OBJECTIVES

Under the terms of the Contract, Meteorology International Incorporated was presented with the following objectives:

a. Using FNWC data, fields and analysis programs, develop an analysis system and produce a 20-year period of analyzed 6-hourly sea-level pressure fields.

b. Using the sea-level pressure fields so produced, compute the sea-level wind fields with the FNWC empirical wind algorithm.

Under the terms of the amendment the following objectives were added:

c. Using FNWC data, extend the data base used for producing the sea-level pressure fields to cover the additional period 1946-1955.

d. Produce a 10-year period (1946-1955) of analyzed 6-hourly sea-level pressure fields and combine these with the fields for the 20-year period resulting from the performance of task a. above.

e. Using the sea-level pressure fields produced for this additional 10-year period, compute the sea-level wind fields with the FNWC empirical wind algorithm and combine these with the fields for the 20-year period resulting from the performance of task b. above.

3. DATA BASES AND DATA BASE PREPARATION

3.1 Tape Data Family-11 (TDF-11)

The original data base of marine observations initially covered the period 1854-June 1968 and is held on a set of tapes known as TDF-11. At later stages supplements were added, extending the period covered to 1974. The data is held in Binary Coded Decimal (BCD) format and contains the full marine synoptic report. The FNWC copy of TDF-11, including Supplements, occupies over 550 large-reel magnetic tapes, the total number of reports being in excess of 50 million. The reports in this FNWC "Marine Deck" are organized by Marsden square; within each Marsden square they are organized by year, and then by month. This organization is suitable for the compilation of climatological summaries but is inappropriate for synoptic analyses.

3.2 Development of the Synoptic Marine Deck[1]

To establish a synoptic data base suitable for the proposed re-analysis of Marine History, the Marine Deck outlined in Section 3.1 was processed to extract, synoptically organize, and compact the observed values of sea-level pressure, and wind direction and speed, for the period 1946-1972. In addition, observed values of sea-surface temperature were extracted to be available for other projects. Data for the years 1973-1975 required to complete the 30-year period was to be provided by marine data obtained by FNWC during the course of conducting routine operational synoptic analyses

[1] Some of this work, carried out by MII, was part of a contract other than the one covered by this Report. However, a brief account of the work has been included as being relevant to the overall development of the re-analysis of Marine History.

of sea-level pressure. However, as indicated in Section 1, the procedure eventually adopted was to re-analyze to 1971 then "add on" the high-quality analyses produced by FNWC to cover the period 1972-1975. Figure 1 shows the sources of available data for marine observations and other information available for this project.

Table 1 shows the distribution of marine observations available for the period 1946-1972. (Note that from 1971 onwards, the Marine History was completed by "adding on" the high-quality FNWC routine synoptic analyses.)

3.3 Additional Data Base Requirements

3.3.1 Introduction

Any hemispheric analysis of sea-level pressure cannot be performed using marine observations only. The major design problems associated with the re-analysis of sea-level pressure to provide the Marine History centered on the requirement to merge, in each analysis, several sources of relevant data.

The first source, of course, was the collection of ships' reports contained in the Synoptic Marine Deck (see Section 3.2). This collection is superior to any previously made[2], and contains reports which were not available when the real-time synoptic analyses were carried out. However, the Marine Deck, in any of its forms, contains only ship reports. To carry out the hemispheric re-analysis, land reports were essential, particularly those from island and coastal stations; but no ready-made collection of land

[2] By April 1978, MII will have compiled a "Consolidated Data Set" containing over 30-million ships' reports for the period 1946-1977. This data set is organized chronologically and geographically (Marsden square).

Observations

Marine Deck	TDF-11	1946-1968
	TDF-11 Supplements	1966-1972
FNWC	Raw Data	1966-1970
	Binary Pack	1970-1975

Sea-Level Pressure Fields

Analogue Source Deck	1/day	1946-1955
	2/day	1956-1959
	1/day	1960-1964
	2/day	1965-1975
FNWC Analyses	4/day	1963-1975

500-mb SR Fields

Analogue Source Deck	1/day	1946-1955
	2/day	1956-1959
	1/day	1960-1964
	2/day	1965-1975

Fig. 1 Available Data

Table 1
Distribution of Marine Observations

1946 - 1955		1956 - 1972	
1946	82047	1956	485151
1947	151458	1957	578652
1948	199742	1958	634841
1949	431867	1959	628311
1950	512806	1960	669582
1951	557249	1961	662345
1952	609467	1962	619933
1953	646077	1963	545462
1954	634911	1964	1068188
1955	596075	1965	1299822
Total 1946-1955:	4421699	1966	1361953
		1967	1310162
		1968	898795
		1969	891477
		1970	612622
		1971	469351
		(1972	331351)
		Total 1956-1971:	12736647

Note: The numbers given for the period 1946-1955 include all observations, including those made at times other than the main synoptic hours (00Z, 06Z, 12Z, 18Z). About 10% of the total observations for this period were "off-time" reports and were not utilized in the re-analysis of Marine History. However for the period 1956-1972 the numbers given represent only main synoptic-hour reports. Thus the total number of observations utilized in the 30-year re-analysis period was somewhat in excess of 16 1/2 million.

reports was available which could make any significant contribution to the re-analysis, and, because of the magnitude of the task, such a collection could not be undertaken.

3.3.2 Historical Analyses of Sea-Level Pressure

The problem of acquiring the information content provided by land observations, without actually assembling a data base of individual reports, was resolved by the use of the historical surface-pressure analyses--these fields include all relevant land, island and ship reports which were available at the time the analysis was performed. These fields were the second source of data. It was not known, however, which stations actually contributed reports to each synoptic analysis of the available history. The problem of extracting the essential information from each historical field, and effecting its assimilation into the re-analysis, was the major challenge of the re-analysis project. How this was done is described in Section 4.2.1.

Ideally, of course, 6-hourly historical fields of sea-level pressure were required, covering the same period as for the proposed re-analysis. Figure 1 shows the fields actually available. The two sources of historical sea-level pressure fields were merged to produce a complete series. Missing fields were generated by combining the forward-in-time kinematic extrapolation of the nearest earlier field with the backward-in-time extrapolation of the nearest later field.

3.3.3 Historical 500-mb SR Fields

Another source of information for any particular analysis of a meteorological parameter is the preceding analysis; i.e., information that has been carried along the time axis.

In order to carry information along the time axis by kinematic extrapolation, a steering field is required. This was provided by the 500-mb

SR fields[3] [1]. Figure 1 shows that these fields were available either twice per day or once per day. Because the steering fields are of large scale and are relatively slow-changing compared with sea-level pressure patterns, it was not considered necessary to extrapolate these fields to produce a 6-hourly set. For the purposes of kinematic extrapolation the analysis system searched for and used the nearest-in-time SR field; on occasions where an SR field occurred at equal time intervals in the future and in the past, the latter was utilized.

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[3] A 500-mb contour field may be considered as made up from two components:

a. The small-scale disturbance (SD) component which encompasses minor troughs and ridges, and the mobile cyclones and anticyclones.

b. The Scale-separated Residual (SR) component which is left after diffusing away the SD component.

The field of the SR component, representing the large-scale features of the circulation, provides kinematical steering terms for the small-scale (SD) features of the circulation. A full description of the system is given in reference [1].

4. DESIGN OF THE RE-ANALYSIS SYSTEM FOR SEA-LEVEL PRESSURE

4.1 The Fundamental Analysis Technique

The Fields by Information Blending (FIB) methodology, devised and developed solely by MII under Navy contracts, is a comprehensive technique for the objective analysis of scalar and vector fields. Essentially, the technique treats information as a metered quantity, each estimate of the magnitude of a parameter (i.e., the observation) being assigned an associated estimate of its worth. This estimate of worth is termed its "weight", which is defined by the inverse of the associated variance. The FIB technique is based on rules for adding uncorrelated variance contributions and for adding independent information. It can directly assimilate the information content of observations (random samplings in space and time) of any required parameter, and information from data assimilated into previous analyses.

To date, applications of the FIB methodology have been developed for the objective analysis of sea-surface temperature, sea-level pressure, horizontal winds, upper air heights, ocean thermal-structure parameters and the climatology of ocean thermal-structure parameters. These objective analysis programs are part of the FNWC operational job stream. The latest major development, FIB Weighted Spreading (FIBWS), was made as recently as February 1976 and has already been applied to the analysis of upper-air height fields (FIBWS/UA-NH) [2]. Experience gained in this application was used in developing the system for the re-analysis of sea-level pressure (FIBWS/PSMAR) carried out in this project.

4.2 Data Sources Providing Information to be Blended

The input data for analysis at each map time consisted of:

a. The Synoptic Marine Deck for the current map time. (See Sections 3.2 and 3.3.1.)

b. The history field for the current map time. Missing history fields were generated by forward-and-backward extrapolation. (See Sections 3.3.2 and 3.3.3.) The technique for exploiting the information contained in these fields is discussed in Section 4.2.1.

c. The field previously analyzed. The available sea-level pressure history had, in general, been analyzed in real time with some (usually unknown) degree of forward-in-time continuity for exploiting the information contained in the preceding-in-time analysis. In order to maximize the yield and utilization of information, the re-analysis was designed to progress backward-in-time. Both the available history field, which included forward-in-time continuity, and the kinematically extrapolated field representing backward-in-time continuity, contribute to the re-analysis.

d. The steering field for the backward-in-time kinematical steering extrapolation. (See Section 3.3.3.) The steering field is based on the geostrophic wind derived from the SR-component of the 500-mb height field nearest to the current map time, this wind being reduced by multiplying by a specified factor (0.58) to provide the steering parameter. The generation of parameter initialization fields by kinematical steering extrapolation has been in use for a number of years and will not be discussed in detail in this Report. However, two possible refinements to

the technique were developed during the course of this project, and these are discussed in Section 4.2.2.

4.2.1 Design for the Exploitation of Available History Fields

A pseudo-report was formed for each grid point at which one or more land and island reports would normally have been assembled. These pseudo-reports served in lieu of the reports unavailable to the re-analysis.

The pseudo-report value of pressure p, is the arbitrary grid-point value, $p_{\ell,m}$, taken from the concurrent history field. The weight[2] $A_{H,\ell,m}$ associated with the pressure $p_{\ell,m}$ was taken to be given by

$$A_{H,\ell,m} = 0.5 + \varphi(d) \qquad (1)$$

where $\varphi(d)$ is a function of the distance inland (d) such that $\varphi(d)$ increases as d increases.

But what if the station reports at a grid point were missing when the history field was analyzed? The pseudo-reports are of questionable validity, and hence they should be individually "questioned" before acceptance. If, when evaluated[3] against other local information, such a pseudo-report cannot be rejected, then it should be accepted as being a realistic estimate of the true pressure at the time of the analysis; the better the agreement with the local information the greater the weight that should be assigned to $p_{\ell,m}$. However, if the pseudo-report does not agree with local information of known value and weight, then it must be

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[2] See Section 4.1.

[3] The evaluation process involves consideration of both numerical values <u>and</u> associated weights.

assumed that the historical analysis was incorrect at that point, and the weight assigned to the pseudo-report should be reduced accordingly. FIB methodology can perform this function.

A FIB analysis generally includes three analysis cycles; i.e., the analysis is performed three times. Before each cycle, all reports are checked and re-evaluated; the tolerances progressively become more stringent.

The pseudo-reports were essentially withheld from the first-cycle analysis, only the reliable information being assembled and blended. The pseudo-reports were then evaluated against the results (grid-point values and resolution weights) of the first-cycle analysis. The pseudo-report weights were adjusted, or set zero, accordingly. The pseudo-reports were assembled in the second cycle but with a reduction factor applied to the weights. Then they were re-evaluated for assembly in the third cycle.

The analysis was designed to include a history-field evaluation and assembly component in all three cycles. The corresponding weight field, before evaluation, is defined by Eq. (1). Evaluation applies a weight reduction factor which was individually calculated for each pseudo-report. A common weight reduction factor also was assigned to the pseudo-reports in each cycle. These were set at 0.05, 0.3 and 1.0, respectively. The first factor is small enough to amount to withholding information for purposes of evaluation. The second factor allows partial assembly for interaction at a distance in the subsequent re-evaluation.

Missing history fields (see Fig. 1) were filled in by kinematical steering extrapolation. In these cases the weights of the pseudo-reports were reduced to a small value at island locations and along coastlines. This reduction progressed inland as the extrapolation time period increased.

4.2.2 Refinements to the Design of the Kinematical Steering Extrapolation

Two possible refinements to the technique for kinematical steering extrapolation were considered. These are:

a. Prior to the steering extrapolation, remove the diurnal component corresponding to map time. After steering extrapolation, add back the diurnal component corresponding to the new map time.

b. Inclusion of an empirical development term based on the meridional displacement component in the steering parameter.

Refinement a , the diurnal component at a grid point for each of the main synoptic hours, was determined by calculating the difference between the mean pressure for a specified main synoptic hour, and the overall mean pressure at the grid point. This refinement was incorporated in the re-analysis system.

The possible inclusion of a "development" term, refinement b , was based on the concept of conservation of absolute vorticity. The implication is that, in the northern hemisphere, "lows" and "highs" moving northward will drop in pressure, albeit slightly on the average, and when moving southward will rise in pressure. Before the steering displacement a latitude term is added to the pressure field:

$$\left(p - pd\right)_{\tau-1} + L\left(\theta\right) \quad .$$

After steering displacement the same latitude function is subtracted:

$$\left[\left(p - pd\right)_{\tau-1} + L\left(\theta\right)\right]_{\tau} - L\left(\theta\right) \quad .$$

The actual function can be tuned statistically for a sample of cases by averaging the changes in the displacement frame of reference. This tuning

should be restricted--in the interests of improvement in the first-guess low-pressure centers--to the subset of grid-point pressures of less than 1000 mb. In practice this function is tuned in conjunction with tuning the speed reduction factor on the steering velocity field, for optimum combined effectiveness.

The latitude parameter was found to increase monotonically with increasing latitude, on average of the order of about 1-mb per degree. However, the spread of values was found to be large and this refinement was not included in the re-analysis system.

5. OUTPUT FORMATS FOR THE RE-ANALYSIS OF MARINE HISTORY

The data sources described in Section 3 were provided as input to the analysis system described in Section 4, thus generating 6-hourly fields of sea-level pressure on a 63x63 grid for the Northern Hemisphere. These fields were stored on magnetic tape, initially in a high-density MII format (9-track tape; 1600 b.p.i.). This allowed two years of history to be stored on each tape. Subsequently the MII format was converted to the required NEDN format (7 track tape) for delivery to FNWC. This storage density allowed only one year of history to be stored on each tape.

For each pressure field, the following statistics were computed and stored in the identification portion of the completed analysis:

a. The number of accepted pressure reports (A).

b. The percentage of reports rejected out of the total available (R).

c. The minimum pressure (grid-point) value in the field (N).

d. The maximum pressure (grid-point) value in the field (X).

e. The mean pressure change from the previously (+6 hr) analyzed field (C).

f. The mean pressure difference from the concurrent history field (D).

g. The maximum absolute pressure (grid-point) difference from the history field (M).

The letters in parentheses, above, identify each item in the summary. As an example, a summary appearing at the remote terminal as

64123012 532A 2R 962N 1036X 1C 1D 21M

was stored in the field identification as

FIBWS/PSMAR 532A 2R 962N 1036X 1C 1D 21M .

(The date-time group appears elsewhere in the identification.)

A plotting package has been written[1] for the user who has only to begin the proper catalogued procedure at a terminal. This activates an interactive program in which the user can specify various options and the dates to be plotted. The user can request plots with or without data and can specify that input information be read from tape or disk. The tape numbers are computed by the program from the plotting dates. Plots of history fields or the newly analyzed FIBWS/PSMAR fields, or both for comparison purposes, can be requested. The plotting date-time groups can be entered in three different forms in the interactive program:

a. Separate year, month, day and hour lists.

b. First and last DTG and increment.

c. List of date-time groups.

The first form can be used to plot, for example, a single day and hour in each month for several months, or any other combination of years, months, days and hours. The second form will be useful for obtaining a series of charts. The third form allows plots for any desired times and should be used when several isolated analyses are required. The date-time information need not be entered in any special order. The only requirements are that not

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[1] Although not part of the contract covered by this Report, an account of the plotting package has been included as being relevant to the overall Marine History project. This was delivered to FNWC in mid-July 1977.

more than 12 analysis times be requested in any one run, and that not more than a two-year period, as stored on a single tape, be included in a single run. (The tapes begin with an even-numbered year and end with the following odd-numbered year; e.g., 1964-1965.)

In addition to magnetic tape storage, an output program has been devised[1] which stores two months of pressure fields (4 per day) on one sheet of microfiche. This form of output allocates a numerical character (0 through 9) to each 10-mb pressure range and, on the viewing screen, the eye-integrated appearance of blocks of numerals (corresponding to pressure zones), gives the impression of contoured bands. This technique allows very compact storage of a large number of fields, making them readily accessible for visual inspection. A preliminary microfiche presentation was used by MII for quality control purposes during the production runs. The final microfiche presentation developed allows the re-analyzed Marine History to be rapidly searched for synoptic sequences of interest (e.g., major storms in a specified area), and the selected sequences extracted and plotted from the magnetic tape storage.

Figure 2 shows an example of an historical sea-level pressure field for 12Z 21 JAN 54; Fig. 3 shows the historically-archived synoptic situation 24 hours later, i.e., at 12Z 22 JAN 54. Figures 4 through 8 show the sequence, in 6-hourly intervals, resulting from the re-analysis. This sequence demonstrates the space-and-time continuity contained in the Marine History. Comparison of Fig. 2 with Fig. 4, and Fig. 3 with Fig. 8, demonstrates the improvements resulting from the superior analysis methodology. As would be expected the two pairs of fields to be compared are superficially similar. However careful study soon reveals many significant differences of detail.[2] For example, the very intense depression

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[2] Note that the re-analysis system used historical analyses for land-area information (see Section 4.2). Thus the significant differences occur over oceanic and coastal regions.

(966.2 mbs) near Greenland on Fig. 8 is shown as a markedly less-intense depression (976.8 mbs) on Fig. 3. Needless to say this disparity causes very large differences in diagnosed winds to the southwest of the storm center.

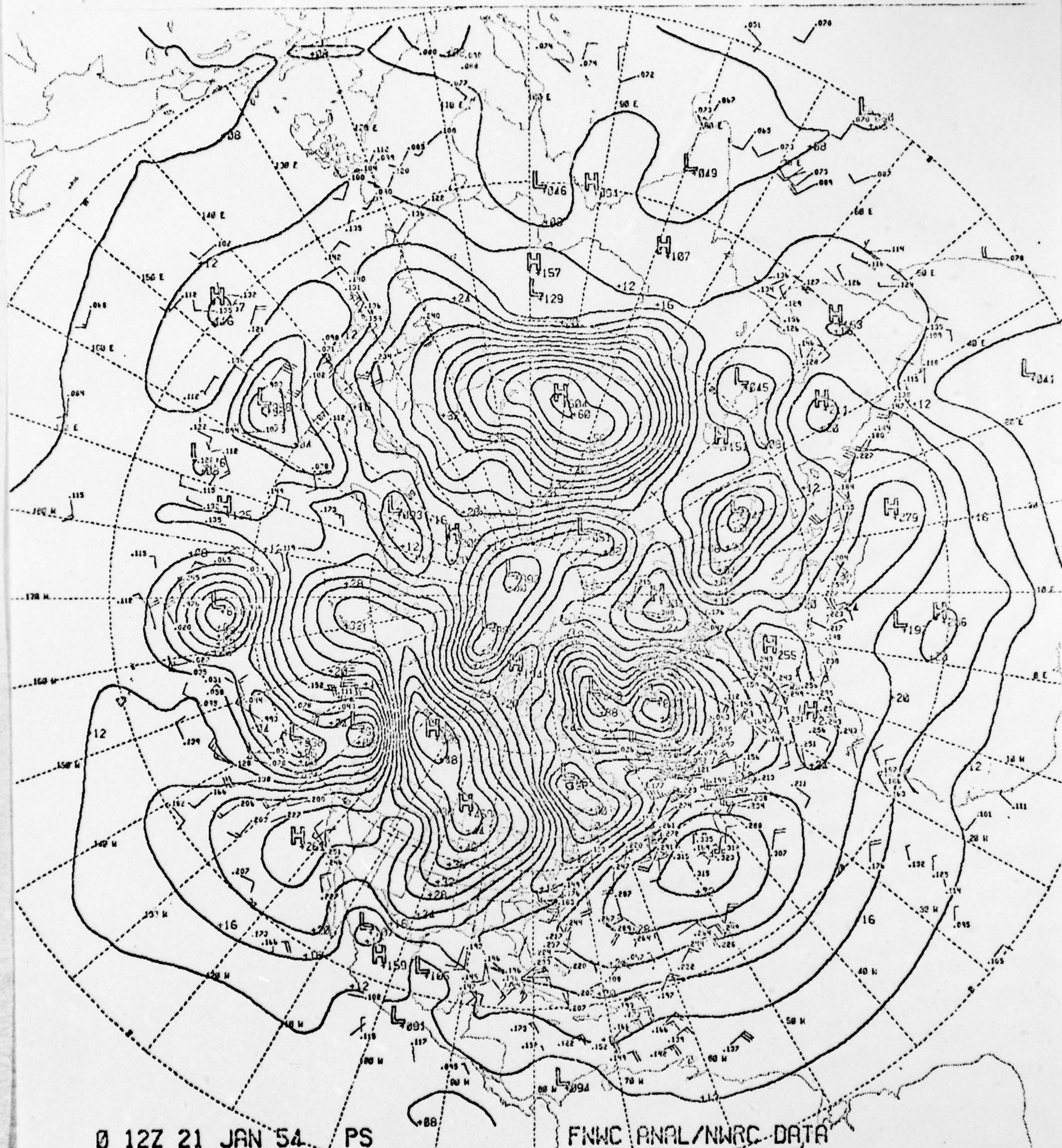
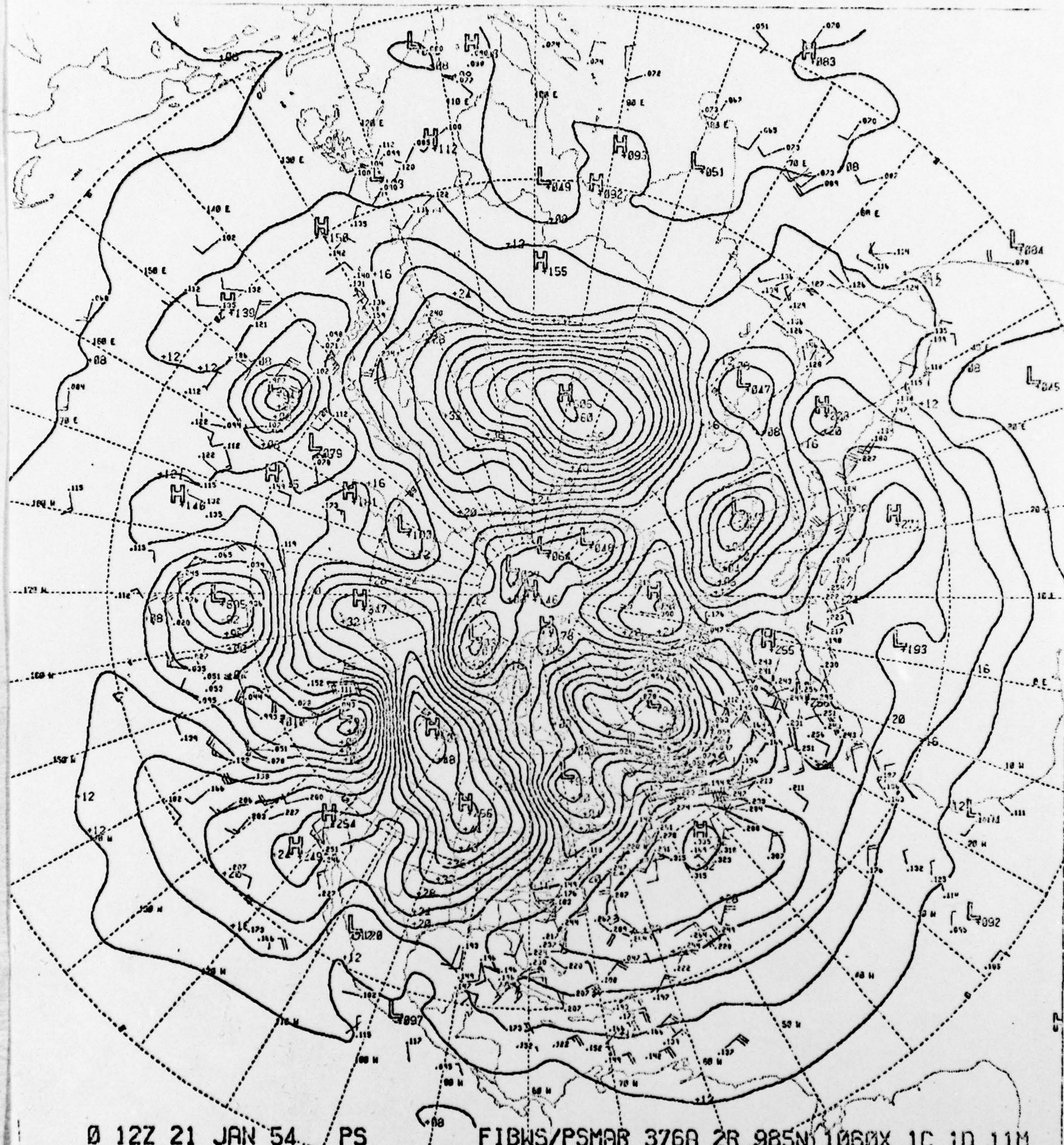

0 12Z 21 JAN 54 PS
FNWC ANAL/NWRC DATA
FLEET NUMERICAL WEATHER CENTRAL U. S. NAVY

Fig. 2

Fig. 3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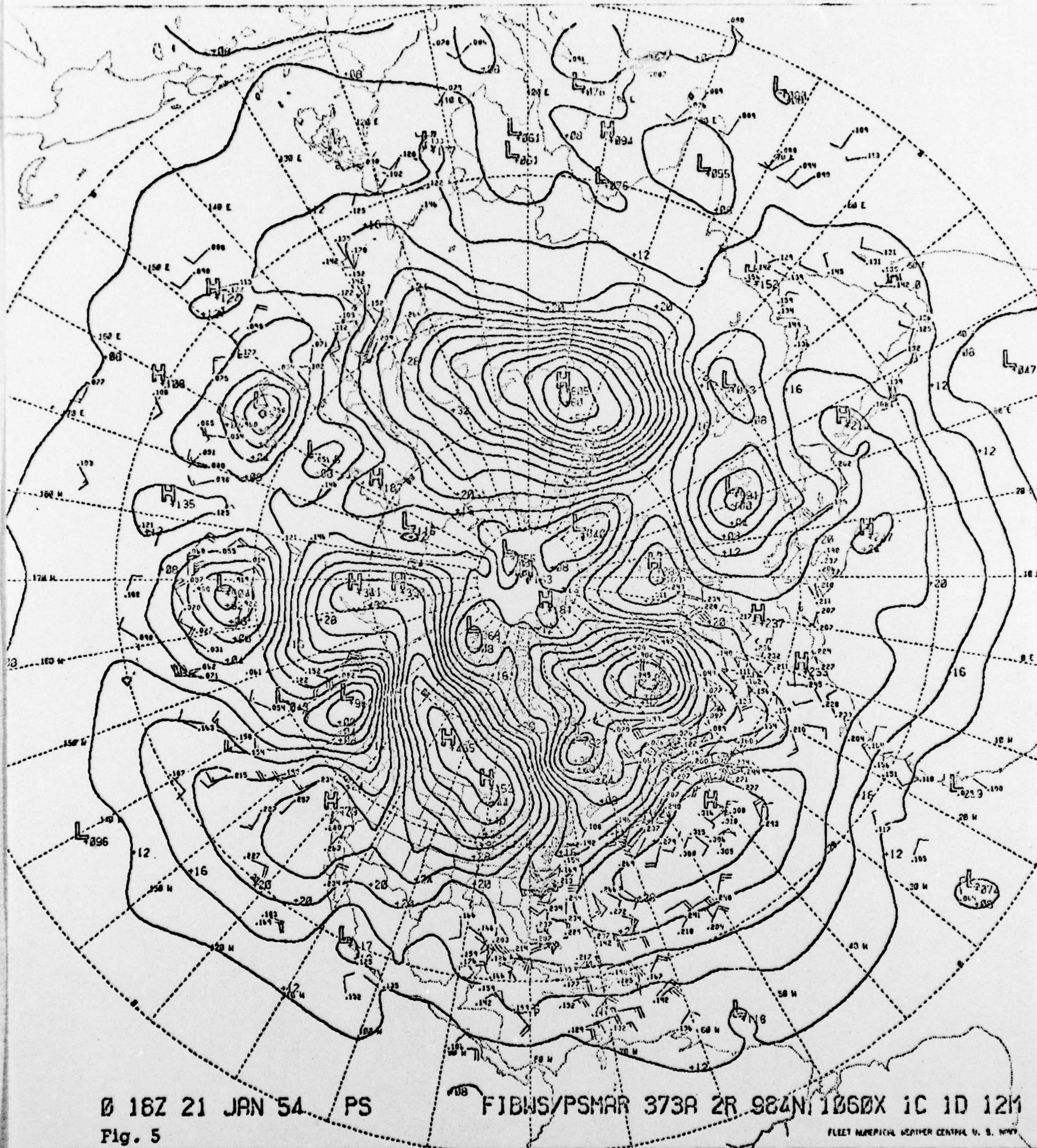
FLEET NUMERICAL WEATHER CENTRAL U. S. NAVY

Fig. 4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FLEET NUMERICAL WEATHER CENTRAL U. S. NAVY

Fig. 5

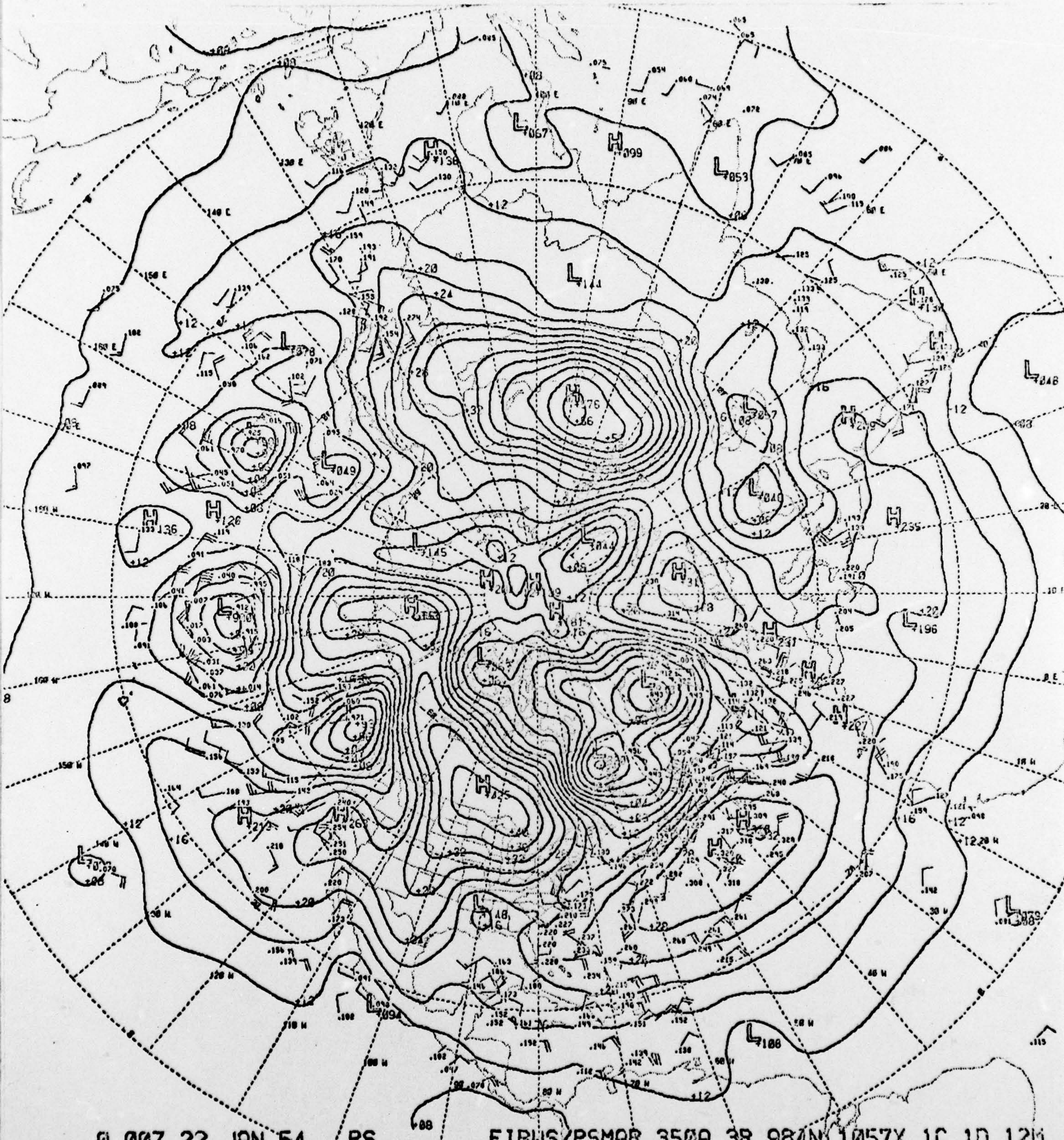
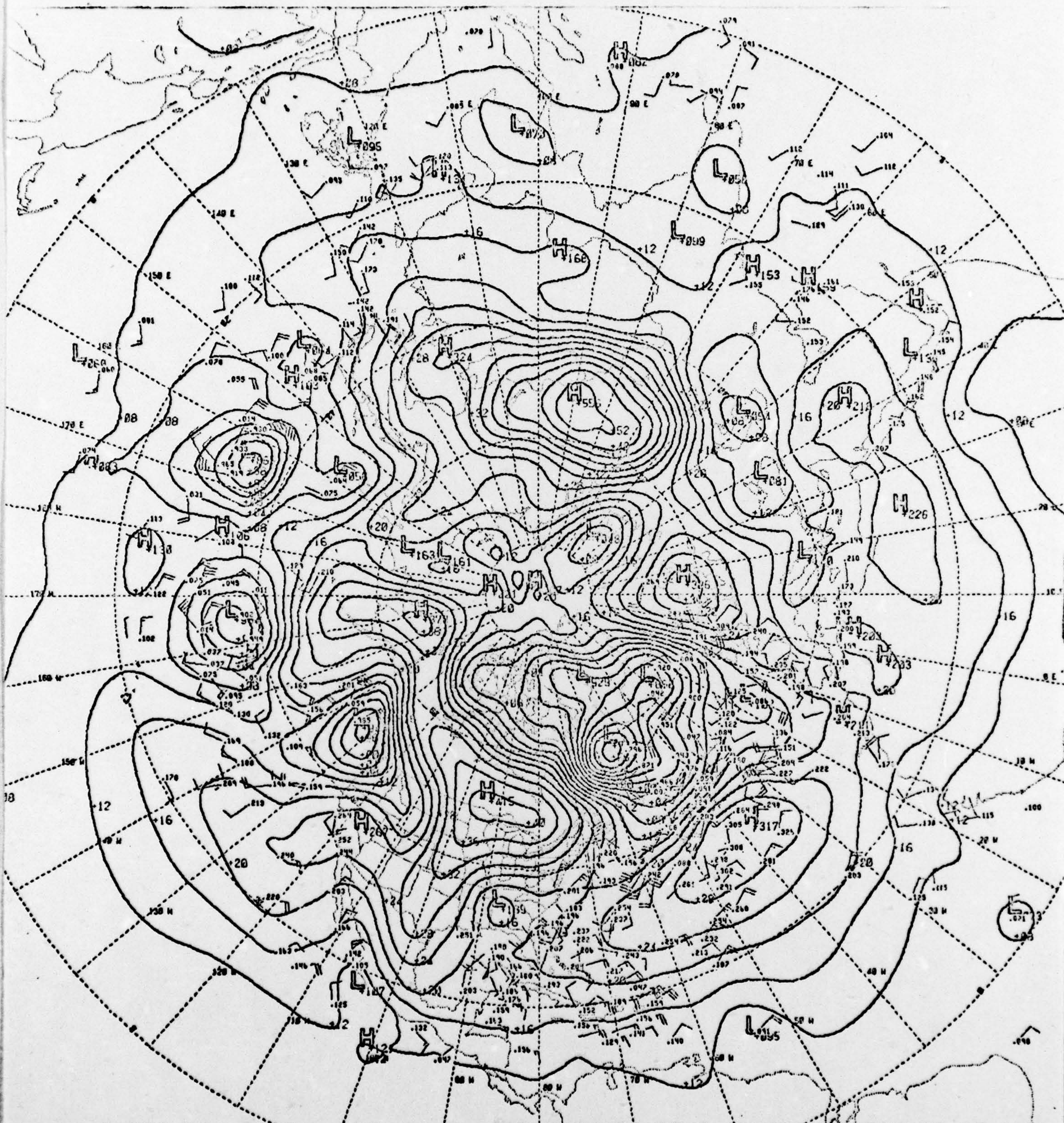


Fig. 6



Ø Ø6Z 22 JAN 54 PS FIBWS/PSMAR 364A 1R 975N 1056X 1C 1D 11M

Fig. 7

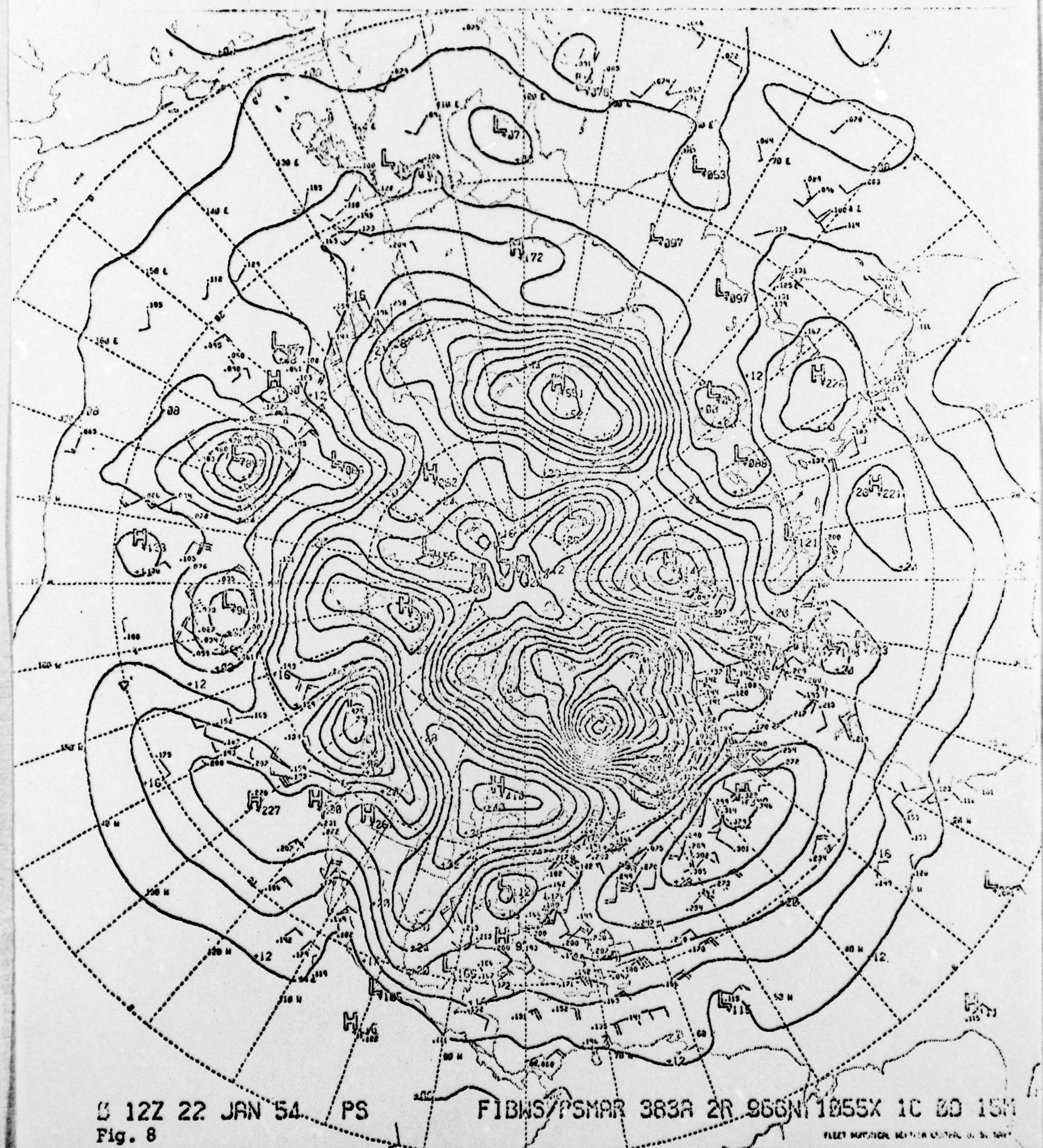


Fig. 8

6. THE DIAGNOSED WIND FIELDS

6.1 The Wind Algorithm

Wind fields (speed and direction) were diagnosed from the pressure fields using the algorithm originally developed by MII for FNWC for use in the FNWC Singular Sea/Swell Model [3]. This wind algorithm was examined in detail by both FNWC and MII with a view to effecting improvements. However, no modification to the formulation could be devised which gave a significant overall improvement.

The wind fields were diagnosed for the FNWC 63x63 grid, and stored on magnetic tape. Originally storage was in the high-density MII format (see Section 5) but this was subsequently converted to the required NEDN format.

6.2 Inherent Limitations in Deriving Winds from Pressure Fields

Certain limitations are inherent in any derivation of winds from pressure gradients and these should be recognized before such winds are used for any purpose, such as wave generation.

In any analysis of the pressure parameter, including FIB analyses, winds are incorporated only to the extent that they help resolve the pressure gradient. If the gradient derived from a wind is in pronounced disagreement with the analysis resolution of the gradient, then that wind is rejected even though it may be a valid wind--valid in the sense that it actually did occur. It follows that the wind derived from the pressure analysis will not then match the reported wind; i.e., the process is not necessarily reversible.

The basic problem is one of scale in space and time--the pressure gradient determined from pressure observations is not (necessarily) the same pressure gradient of which the wind is a measure. As a simple

example, consider a pressure field in which the curvature is changing rapidly. Given a sufficient density of pressure observations the instantaneous pressure field could be resolved using pressure information only. However, it takes space and time for an airstream to adjust to curvature, so observations of wind made simultaneously with those of pressure will not be in agreement with winds diagnosed from the instantaneous pressure field.

6.3 Evaluation of Diagnosed Wind Speeds versus Observed Wind Speeds

In effecting the pressure field-to-wind field transformation, it was obviously necessary to use an algorithm which was capable of reflecting the high quality of the re-analyzed pressure fields in the diagnosed wind fields. As stated in Section 6.1 the algorithm used was that originally developed by MII for use in the FNWC Singular Sea/Swell Model. In order to check the effectiveness and validity of this algorithm for use with the re-analyzed pressure fields, a statistical analysis of diagnosed wind speeds versus observed wind speeds[1] was carried out.

Table 1 (page 8) shows the distribution of marine observations by year. Two years were selected (1964 and 1965, together representing over 2.3 million wind reports from ships) and actual wind speeds were compared with wind speeds diagnosed from the re-analysed pressure fields using the wind algorithm. In making the comparison, of course, the diagnosed wind speeds were for the same location as the corresponding reported wind speed.

Figure 9 shows a scatter diagram with reported wind speeds plotted along the ordinate and corresponding diagnosed wind speeds plotted along the abscissa. All speeds are in meters per second rounded to the nearest integer value. In constructing the diagram, winds have been divided into classes. The numbers in the body of the scatter diagram show the number

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[1] Previous investigations have determined that the wind algorithm produces no systematic bias with regard to wind direction.

Diagnosed Wind Speed (meters/second)																					
20																					
19													1			1					
18													1			1					
17										1	1		2			2			1	1	
16										1	1	1	3	1	1	2			1	1	
15								1	1	2	2	1	4	1	1	3	1		1	1	
14							1	1	2	3	3	2	5	2	1	4	1		1	1	
13					1	1	2	2	3	5	5	3	6	2	1	4	1		1	1	
12					1	2	4	4	5	7	7	4	8	3	2	4	1		1		
11			1		3	3	6	6	7	10	9	4	9	3	2	4	1		1		
10			1	1	4	5	9	9	10	13	12	5	10	3	2	4	1				
9	1	1	3	2	8	9	14	14	14	16	14	5	10	3	1	3					
8	1	1	5	4	12	14	20	20	18	18	16	5	9	2	1	2					
7	2	2	8	7	18	21	26	25	21	18	15	5	7	2	1	1					
6	4	5	14	12	26	29	31	28	21	16	13	3	5	1		1					
5	6	7	19	16	31	34	31	27	18	12	9	2	3	1							
4	10	12	28	21	37	37	29	22	13	9	6	1	2								
3	15	18	37	26	37	34	22	16	9	5	3	1	1								
2	18	19	33	21	26	22	13	8	5	2	1										
1	14	14	22	13	15	12	6	4	2	1											
0	2	2	3	2	2	1	1														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Observed Wind Speed (meters/second)

Fig. 9 Scatter diagram showing observed wind versus diagnosed wind by class. Numbers on scatter diagram show lower-bound numbers (in thousands) of occurrences in each class.

(in thousands) of observed versus diagnosed wind speeds for each class, with the number shown being that of the lower bound of each class. Thus, for example, Fig. 9 shows that there were between 29000 and 29999 cases where reported wind speeds of 5 meters per second were diagnosed as 6 meters per second. Note that any class containing less than 1000 reports (i.e., about 0.04% of the cases) will not be shown in the scatter diagram.

As discussed in Section 6.2, the various scales of atmospheric disturbances in space and time which determine observed winds are not (necessarily) the same as those which determine winds diagnosed from pressure fields. An important test of an effective algorithm for diagnosing winds from pressure fields is, therefore, that there is no statistical bias in the results--in other words, that diagnosed winds of a certain value correspond, in the mean, to the same value of observed winds.

From the 2.3 million observations available for 1964-1965 a correctly-derived line of best fit[2] was calculated. The slope of this line was 0.982:1, showing that, on average, diagnosed winds are approximately 1.8% low when compared with observed winds. It is considered that this mean difference is insignificant for practical purposes and, consequently, that the wind algorithm employed is both effective and realistic in deriving diagnosed winds from pressure fields.

Although not directly relevant to this discussion, Fig. 4 shows several features worthy of comment. Note, for example, that observed

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[2]The correctly-derived line of best fit is one which minimizes the squares of the differences perpendicular to this line. This may be compared with the commonly (and mistakenly) used "least-squares fit" which minimizes the squares of the differences along one coordinate only. This method applied to the data represented by Fig. 4 suggests that diagnosed winds are either 30% higher or 30% lower than observed winds, depending on which of the two winds is considered to be the dependent variable.

winds of 0 meters/second rarely result in diagnosed winds of the same value; this is due to the fact that a finite grid spacing cannot easily represent very weak gradients. Also note the uneven (and unlikely) class distribution of observed wind speeds for a selected value of diagnosed wind speed.

7. POTENTIAL USES OF THE RE-ANALYSIS SYSTEM AND ASSOCIATED DATA BASES

7.1 Summary of Data Bases

As a result of this and associated projects, the following data bases are now available:

a. A data base of marine observations. (See Sections 3.1 and 3.2.)

b. A 6-hourly sequence of "state-of-the-art" Northern Hemisphere sea-level pressure analyses for the period 1946-1975 on a 63x63 grid, polar stereographic projection.

d. Wave fields generated by the FNWC Spectral Wave Model using the diagnosed winds as input. (These fields are not yet complete.)

7.2 Extension of the Period of Re-analysis and the Re-analysis System

The re-analysis of Marine History was originally intended to cover a 20-year period, 1956-1975, and subsequently was extended to cover the 30-year period 1946-1975. As discussed in Section 1, no actual re-analysis was carried out from the beginning of 1972--the synoptic analyses of sea-level pressure routinely produced by FNWC were adjudged to be of comparable quality from that time onwards. Of course this is now an on-going process and the Marine History of sea-level pressure and surface winds can be updated to concurrency as desired. An improvement in analysis quality due to increased data coverage is anticipated as soon as the satellite-derived SASS winds form part of the operational input. MII is currently engaged in expanding the FNWC analysis system for sea-level pressure to produce global analyses able to incorporate the gradient information expected from SASS winds (SEASAT-A).

Apart from "real-time" additions to the Marine History, the overall system now exists to extend the period of sea-level pressure re-analysis, and the associated generation of wind and wave data. Data bases--marine observations and digitized fields--exist which should allow the re-analysis system to be operated to as far back as the turn of the century. This could produce a data base of sea-level pressure fields, diagnosed wind fields and wave fields, analyzed every 6 hours for a period of 80 years.

In addition, development of a finer-mesh analysis system for a limited area would allow those significant variabilities to be captured which are not revealed by the 63x63 grid system utilized in this project.

7. Uses and Application

The data bases outlined in Section 6.1 represent the most accurate, detailed and comprehensive marine information available to date for the Northern Hemisphere. There exists a wide variety of theoretical and practical applications for the data. Such applications include the determination of short-term climatological trends in surface pressure patterns; the compilation of wind and wave statistics for use in ocean routing, ship and platform design; the effect of winds and waves on operations, both military and civilian; synoptic studies; coastal studies; and so on. Many of these potential applications will require the use of retrieval systems being developed by MII (see Section 5).

Some potential applications may require further development work such as extension of the period of re-analysis or the use of a finer-mesh analysis system. Such a system would allow more realistic compilations of wind and wave statistics to be made in local areas such as the Mediterranean or the North Sea. Also, the wind fields on any scale of analysis could be used to drive wave models other than the FNWC Spectral Wave Model.

Using the Consolidated Data Set (footnote 2, page 6), MII intends to produce a 30-year global data base of analyzed sea-surface temperature fields, and sea-surface temperature anomalies, in terms of 5-day means. The fundamental analysis methodology (FIB) is common to the Marine History. Using both the Marine History and the sea-surface temperature fields, it is hoped to investigate the interplay between persistent sea-surface temperature features and climatic regimes and trends.

Optimum use of the data (including generated fields), the overall analysis and retrieval system, and further development work, all require a thorough knowledge and understanding of the techniques used. Meteorology International Incorporated would be pleased to discuss and provide advice on all such uses, applications, and developments.

8. REFERENCES

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[3] Hubert, W. E. and B. R. Mendenhall* (* Meteorology International Incorporated), The FNWC Singular Sea/Swell Model, Technical Note 59, Fleet Numerical Weather Central, Monterey, California, 1970.